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APPLICATION FOR LETTERS PATENT

**UNIVERSAL SERIAL BUS TRANSCEIVER
AND ASSOCIATED METHODS**

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UNIVERSAL SERIAL BUS TRANSCEIVER AND ASSOCIATED METHODS

CONTINUATION APPLICATION

[0001] This Patent application is a continuation of U.S. Patent application number 09/861,297 filed May 18, 2001, which is a continuation of U.S. Patent application number 09/239,624 filed January 28, 1999. The present application reproduces material previously incorporated by reference from U.S. Patent application number 09/239,494 filed January 28, 1999.

FIELD OF THE INVENTION

[0002] The present invention is related to high speed signal transmission or communications, such as, for example, in a computing or computer system.

BACKGROUND OF THE INVENTION

[0003] As is well-known, in a computer system, for signal communication to occur between, for example, the computer peripheral and the host computer, today signals are transmitted that comply with a predetermined specification or protocol. This is desirable because it enhances the interoperability between devices manufactured by different entities, for example. One such specification is the well-known Universal Serial Bus specification, version 1.0, available from USB-IF, 2111 NE 25th Ave., MS-JF2-51, Hillsboro, OR 97124, (hereinafter referred to as "Standard USB"). The current version of the specification refers to signals that communicate at a low speed, 1.5 megabits per second, and at full speed, 12 megabits per second. However, with increases in the speed of microprocessors, and the number and speed of the peripherals, it has become desirable that signal transmission occur at even higher signal rates. In addition to this desire for high speed signaling, it is also desirable that new computing or computer systems include the capability to comprehend or communicate with legacy systems that operate at the pre-existing or lower speed signaling rates. Therefore, it is desirable to have a process or technique for communicating at high speeds when that capability exists, while retaining the capability to communicate at low or state-of-the art speeds to maintain backward compatibility.

BRIEF DESCRIPTION OF THE DRAWINGS

[0004] The subject matter regarded as the invention is particularly pointed out and distinctly claimed in the concluding portions of this specification. The invention, however, both as to organization, and method of operation, together with objects, features and advantages thereof, may best be understood by reference to the following detailed description, when read with the accompanying drawings in which:

FIG. 1 is a schematic diagram illustrating portions of embodiments of, for example, two integrated circuits in accordance with the present invention, the integrated circuits being coupled by a cable; and

FIG. 2 is a circuit diagram illustrating an embodiment of drivers that may be employed, for example, in one of the integrated circuits of FIG. 1.

DETAILED DESCRIPTION

[0005] In the following detailed description, numerous specific details are set forth in order to provide a thorough understanding of the invention. However, it will be understood by those skilled in the art that the present invention may be practiced without these specific details. In other instances, well-known methods, procedures, components and circuits have not been described in detail so as not to obscure the present invention.

[0006] FIG. 1 is a schematic diagram that shows an embodiment 100 illustrating portions of embodiments of two integrated circuits in accordance with the present invention. Embodiment 100 includes integrated circuits 200 and 205, although the invention is not limited in scope in this respect. These integrated circuits may be included or incorporated into a variety of systems. For example, without limitation, a host computer and a peripheral in communication with the host computer. As illustrated in FIG. 1, these integrated circuits are coupled via a cable 110, which operates effectively as a transmission line in this context. In this particular embodiment, cable 110 comprises a twisted pair copper wire, although the invention is not limited in scope in this respect. In this particular embodiment, integrated circuit 205 includes an upstream

transceiver and integrated circuit 200 includes a downstream transceiver. In this context, the upstream transceiver transmits communication signals to the downstream transceiver, such as from a host to a peripheral, as mentioned above, although the invention is not limited in scope in this respect. It is also noted that this definition of upstream and downstream is the reverse of the approach employed in the previously referenced standard USB specification.

[0007] The transceivers illustrated are capable of communicating at low speed, that is 1.5 megabits per second, and at full speed, that is 12 megabits per second, for a standard USB transceiver, as well as at a higher speed. In this particular embodiment, the speed of the high speed signals is 125 megabits per second, although the invention is not limited in scope in this respect. Therefore, at low and full speed, the operation, in terms of signals, of this embodiment is substantially identical to standard USB compliant devices or transceivers. However, as shall be explained in more detail hereinafter, the transceiver is self-configurable in that it is capable of operating in a high speed mode, as well as at a low or a full speed mode. To accomplish this, in this particular embodiment, the transceiver configures itself between two architectures, a standard architecture and a high speed architecture. The added circuitry for the high speed architecture is transparent to the circuitry that operates in a manner that complies with the standard USB specification.

[0008] As is well-known, in standard USB, voltage mode drivers are employed with near end series termination. One reason that this approach is undesirable for high speed operation is due to the electromagnetic interference that would be generated by a voltage mode driver operating rail-to-rail at a relatively high speed, such as on the order of 125 megabits per second. A relatively large signal swing in a short period of time, due to the high frequency, may produce an undesirable amount of interference. Therefore, in this particular embodiment, for high speed

operation, current driven circuitry with far end parallel termination is employed instead, as shall be described in more detail hereinafter. Signal transmission using current driven signals, as opposed to voltage driven signals, allows for a smaller, better controlled signal swing, as well as for differential signals. Another advantage of the transceiver embodiment illustrated in FIG. 1 is that the transceiver power consumption is lower in high speed mode at 125 megabits per second, for this particular embodiment, than the power consumption for the transceiver in full speed mode at 12 megabits per second. One reason this occurs is because a smaller voltage signal swing consumes less power.

[0009] In addition to being current driven, in this particular embodiment, the high speed circuitry employs single side termination. Furthermore, in this particular embodiment, the termination is asymmetrical. More specifically, far end termination is employed when communicating downstream, whereas near end termination is employed when communicating upstream. Communication occurs upstream because the cable or bus is bi-directional. Therefore, one advantage of this approach is that it employs fewer additional pins to accomplish termination than alternative approaches.

[0010] Referring to FIG. 1, as illustrated, receiver 120 operates as a low speed and full speed receiver, whereas drivers 130 and 140 respectively operate as full speed and low speed drivers. Of course, 120 could be two receivers as well. The downstream configuration is similar in that receiver 220 operates as a full speed receiver and low speed receiver, whereas 230 and 240 operate as full speed and low speed drivers. Again, 220 could be two receivers also. As illustrated, the circuitry includes the capability to comply with the standard USB specification and it includes the appropriate terminations for satisfactory operation to take place. Therefore, if this transceiver embodiment is communicating either upstream or downstream with a transceiver

that does not include high speed capability, low speed or full speed operation may be employed. Likewise, this transceiver embodiment in accordance with the present invention, illustrated in FIG. 1, includes high speed circuitry so that high speed communication may be employed when communicating with a transceiver that likewise includes a similar high speed capability.

Therefore, referring to the upstream high speed transceiver, high speed receiver 150 and high speed drivers 160 and 170 may be employed, whereas on the downstream high speed transceiver, high speed receiver 250 and high speed drivers 260 and 265 may be employed. Likewise, the high speed portion of the circuitry includes a voltage source, in this particular embodiment voltage source 180 on the upstream transceiver and voltage source 270 on the downstream transceiver, as illustrated in FIG. 1 in this embodiment. These voltage sources may typically comprise bandgap circuits, although the invention is not limited in scope in this respect. In this embodiment, the downstream transceiver also includes a voltage regulator 275, described in more detail hereinafter.

[0011] When communication occurs from the upstream transceiver to the downstream transceiver, far end termination is employed. This occurs in this embodiment because regulator 275 is operational in high speed mode downstream and, therefore, for the downstream transceiver, regulator 275 appears as a relatively low impedance in series with externally supplied resistances 310 and 320. As illustrated, assuming cable 110 in this embodiment has a 90 ohm impedance, such as for a twisted pair of copper wires, resistances 310 and 320 provide a desired far end termination. Of course, the invention is not limited in scope to these resistances. Furthermore, these resistances could alternatively be provided on-chip rather than off-chip.

[0012] In contrast, when communication takes place from the downstream transceiver to the upstream transceiver, near end termination is employed. Therefore, the previously described

termination also provides the desired termination for downstream to upstream communications. This occurs in this particular embodiment because the upstream high speed drivers, such as 160 and 170, are tri-stated and have a relatively high impedance, while the upstream high, full, and low speed receivers are active (and therefore high impedance). Therefore, the signal transmitted from the downstream transceiver to the upstream transceiver is effectively reflected back due to the high impedance of the upstream transceiver. However, the externally provided 45 ohm resistance of 310 and 320 forms a voltage divider with 90 ohm cable 110 so that approximately half of the energy of the signal is transmitted from the downstream transceiver to the upstream transceiver. Therefore, when the signal is reflected back due to the upstream high impedance just described, the original and reflected signal sum constructively at the upstream transceiver to provide the full signal at the upstream receiver.

[0013] As previously indicated, another aspect of this particular embodiment of a transceiver is that the transceiver is self-configurable. This particular embodiment has several different self-configurable aspects, although the invention is not limited in scope to having all these aspects in one embodiment. For example, the transceiver includes the capability to turn the appropriate drivers and receivers on and off depending upon the particular speed of operation that is desired. This capability is not specifically illustrated in FIG. 1, however, in order not to obscure the present invention. However, various signaling protocols may be employed for the transceiver to determine the speed of operation desired and, therefore, configure the drivers and receivers appropriately. For example, although the invention is not limited in scope in this respect, a given transceiver might initially assume operation in a full speed mode and wait for an indication from another transceiver with which it is communicating as to whether that other transceiver is high speed capable. Then if that other transceiver indicates that it is high speed capable, the

transceiver in full speed mode may upgrade its communication speed as appropriate. Of course, the invention is not limited in scope to this technique for establishing high speed communication. Regardless of how this is accomplished, if we assume that a transceiver has the capability through signaling protocols to determine the appropriate mode of operation, then this particular transceiver embodiment is self-configurable in that it may couple the appropriate circuit configurations in order to accomplish the desired speed of operation.

[0014] In this particular embodiment, the self-configuration is accomplished at the downstream transceiver, although the invention is not limited in scope in this respect. For example, this might be accomplished instead by an upstream transceiver. One advantage of this approach is that providing the self-configurable capability employs, in this embodiment, three additional external connections. Therefore, placing these extra connections or pins with the downstream transceiver may ultimately reduce the number of additional pins in a system because, for example, a multi-port device, such as a hub, will typically employ one downstream transceiver yet multiple upstream transceivers. Therefore, this technique reduces the number of extra pins employed in order to have this self-configuration capability since multiple upstream transceivers would result in multiple extra pins if that approach were employed.

[0015] For the embodiment illustrated in FIG. 1, one aspect of this self-configuration capability is exhibited by switch 340 and resistor 330. As is known, one aspect of complying with the standard USB specification is providing a 1.5 kilo-ohm pull-up resistor, such as resistor 330, for full speed mode operation. Therefore, switch 340 may be provided on integrated circuit 200 in this particular embodiment and will remain open for high speed operation and closed for full speed operation. Of course, the invention is not limited in scope in this respect and an additional pin and resistor 330 may be avoided by instead providing a current source that simulates the rise

time specified in the standard USB specification when connection to a cable is accomplished for full speed operation. This is shown in FIG. 1 by a dotted line. In this context, the term “current source” refers to a transistor coupled so that in operation it resembles the circuit characteristics of a current source. In embodiments in which this latter approach is employed, the downstream transceiver may therefore be self-configurable and employ two external connections instead of three external connections.

[0016] As illustrated in FIG. 1, these two external connections are employed to couple two resistors 310 and 320 providing the parallel terminations previously described, although, of course, the invention is not limited in scope in this respect. However, as shall be explained in more detail hereafter, these pins couple these parallel terminations to voltage regulator 275. Providing parallel far end termination for the upstream transceiver is only one aspect of employing voltage regulator 275 in this particular embodiment. As previously described, when voltage regulator 275 is operational, it provides as a relatively low impedance in series with parallel termination resistors 310 and 320. However, in an alternative mode, voltage regulator 275 may no longer operate as a voltage regulator and in this mode of operation may provide a relatively high impedance. This mode of operation for voltage regulator 275 is desirable when full speed or low speed operation is desired for the transceiver, hence, furthering the self-configurability of the transceiver.

[0017] The effect of employing the voltage regulator in this fashion provides for the two different signaling techniques or modes previously described. When the voltage regulator is operational providing a relatively low impedance, this allows the transceiver to perform current mode signaling, as previously described, so that high speed communication may occur. Alternatively, when the voltage regulator is off, and, therefore providing a relatively high

impedance, this allows for voltage mode signaling, as is traditionally employed in standard USB, to take place. Thus, voltage regulator 275 is another aspect of the self-configurability in this transceiver embodiment.

[0018] In addition to providing the capability to disconnect or decouple the parallel termination, as previously described, voltage regulator 275 also sinks and sources current when high speed communication is occurring, while maintaining a substantially constant voltage level.

Maintaining a substantially constant voltage level, particularly above ground, is desirable because it maintains the voltage level of the downstream transceiver at a voltage level so that a high speed receiver may operate satisfactorily. Although the invention is not limited in scope in this respect, one embodiment of such a voltage regulator is described in the aforementioned concurrently filed patent application titled "Voltage Regulator,"(attorney docket 041390.P6877) by M. Beck, assigned to the assignee of the present invention and herein incorporated by reference.

[0019] FIG. 2 is a circuit diagram illustrating an idealized embodiment of high speed drivers for embodiment 205 of an integrated circuit in accordance with the present invention shown in FIG.

1. These drivers correspond to drivers 160 and 170 in FIG. 1, although, the invention is not limited in scope to this particular embodiment. Many other embodiments of high speed drivers may be employed in an integrated circuit in accordance with the present invention. Likewise, as previously described, this particular embodiment assumes far end termination is employed. As illustrated in FIG. 2, each high speed driver in this particular embodiment comprises two switched current sources coupled in parallel. In this context, the term "current source" refers to a transistor coupled so that in operation it resembles the circuit characteristics of a current source. To signal a logical one, the current source in the first driver formed by transistors 510, 520, 530,

540, 550, and 560 turns on, supplying current to the 90 ohm twisted pair cable, and to the terminating resistors 310 and 320, in this particular embodiment. The current source in driver 170 formed by transistors 410, 420, 430, 440, 450 and 460 is also turned on, sinking current from the terminating resistors and the cable. To signal a logical zero, driver 170 sources current and driver 160 sinks current. Assuming about a 500 millivolt signal swing, although the invention is not limited in scope in this respect, that is, the predetermined voltage level of voltage regulator 275 plus or minus about 250 millivolts, a current of about 5.5 milliamps is employed. To reduce electromagnetic interference, it is desirable that the signals produced by the driver be symmetrical, which makes employing substantially identical drivers desirable. It is likewise desirable to match the rise and fall times for the signals produced. It is therefore desirable to size the transistors forming the current mirrors of the drivers appropriately because the size of the transistors affects gate capacitance, which may impact the signal rise and fall times. In this particular embodiment, as illustrated in both FIG. 1 and FIG. 2, two pins are employed for voltage regulator 275. This provides the capability to disconnect or decouple the parallel termination provided by resistors 320 and 310 when desired without allowing these two resistors to form a circuit loop through the voltage regulator. Thus, placing the voltage supply in a high impedance state in order to accomplish full speed operation effectively switches out the parallel terminations from the transceiver, as is desired for this embodiment.

[0020] While certain features of the invention have been illustrated as described herein, many modifications, substitutions, changes and equivalents will now occur to those skilled in the art. It is, therefore, to be understood that the appended claims are intended to cover all such modifications and changes as fall within the true spirit of the invention.